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PHOTOVOLTAIC SYSTEM DESIGN FOR CONSUMERS IN ISOLATED OPERATION

PROJEKTIRANJE FOTONAPONSKIH SUSTAVA ZA POTROŠAČE U OTOČNOM RADU

Igor Petrović, Dinko Begović, Zoran Vrhovski

Preliminary note

Abstract: *All present product suppliers use website with product data, analysis and solutions in order to gain trust from their consumers. In this paper a case study is presented where electrical energy consumption measurement system is used in order to provide design results of minimal isolated PV plant necessary for electrical energy supply system. Measured results are available on-line for registered users. This kind of history data set is sufficient to determine minimal technical demands for future PV plant. Methodology presented in this paper can also be used in design any similar electrical or other energy supply, both in isolated of grid connected operation.*

Keywords: *AMR/AMI, design, energy consumption, photovoltaic*

Prethodno priopćenje

Sažetak: *Danas svi dobavljači proizvoda koriste mrežne stranice s podacima o svojim proizvodima, analizama i primjerima korištenja kako bi stekli povjerenje svojih kupaca. U ovom radu prikazan je način korištenja sustava za daljinsko očitanje brojila električne energije u svrhu projektiranja minimalnih zahtjeva na fotonaponski sustav u otočnom režimu rada za pokrivanje potrebne proizvodnje električne energije za tog potrošača. Rezultati takvih mjerenja potrošnje mrežno su dostupni za svakog registriranog korisnika. Ovako dobivena baza podataka dovoljna je za određivanje minimalnih tehničkih zahtjeva na buduće fotonaponsko postrojenje. Također, metodologija prikazana u ovom radu može se primijeniti u projektiranju bilo kojeg sličnog sustava za napajanje električnom energijom, jednako u otočnom ili mrežnom radu.*

Ključne riječi: *AMR/AMI, fotonapon, potrošnja energije, projektiranje*

1. INTRODUCTION

The renewable energy sources are in present considered as best solution for energy production considering sustainable environmental development, as described in [1]. In big electrical energy distribution networks it is common to implement renewable electrical production systems with no effect to end user. In this paper the case scenario of isolated PV electrical energy production system is analyzed, with certain error span for results, as presented in [2] and [3].

A single professional end user in electrical energy distribution network is randomly selected, and for that user a standard professional design of isolated PV system is conducted, using methods like in [4] and [5], regarding users energy consumption behavioral. The selected user data is privileged and therefore will not be given in this paper. The data about his behavior is gained using measured consumption from electrical energy distributer, and it is concluded that it is not related to daylight. The installed electrical power of this user is not intended to be generalized in Watts, but rather p.u. in terms of maximal power values as this research is meant to give general overview for this type of energy production and consumption. Since most of demands are not admitted for Sun tracking, presented in [6], [7] and [8], fixed PV system is selected for this application. The methods and analysis used in this paper supply designers with input data for appropriate technical documentation on PV system design.

2. DETERMINATION AND DESIGN OF ISOLATED PV SYSTEM WITH LOAD

Most common method for PV system electrical energy production is web database PVGIS, available in [9]. It can provide simple empirical results adjusted to the specific location. Since the results are estimated, not modeled, but gained from empirical measured electrical values, not hydrological average values, it can be considered that the results are enough accurate for this type of research.

The main user parameters for this PV system design are daily consumed electrical energy and maximum electrical consumption power. Designed PV system must be able to obtain enough electrical energy for each day of consummation, and also cover the peak of power for each day. Since the consumer behavioral is not related to daylight it is obvious that isolated PV system must be equipped with energy storage, as presented in Figure 1, PV system configuration is designed to meet all requirements from the consumer. Installed PV modules must gain sufficient energy during a single day with highest energy consumption. Battery bank must be able to store a single day highest energy from PV modules and at the same time provides highest required electrical output power. DC-AC converter must be able to provide required electrical output power.

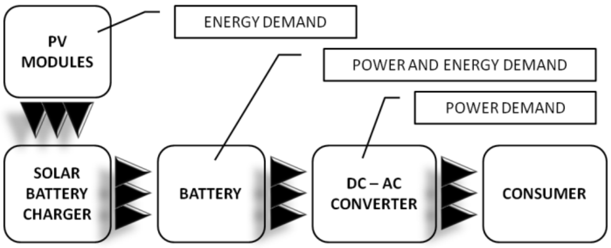

Figure 1. Configuration of isolated PV system with load

All requirements listed in this section are used for basic prediction of PV system electrical energy production using PVGIS. The location of designed PV system is in North-West Croatia.

Finally, the isolated PV system with load design must provide list of parameters as shown here:

- PV module power
- Selected PV module
- Number of PV modules
- Battery bank energy storage
- Battery bank maximum output power
- DC-AC converter maximum output power

3. AMR/AMI SYSTEM FOR MEASURING AND REMOTE SUPERVISION WITH HISTORY DATABASE

Remote meter reading for electrical energy consumption is a technology that allows automatic collecting of measured electrical energy consumption readings. Also, one can gain access to control the readings of measured values, events and alarms from electrical measuring equipment. Those data can be obtained on demand, or periodically according to a predefined schedule. Once the data is available in remote station it is stored in a single database for various analyses, calculations and/or malfunction detection.

HEP ODS upgraded standard basic AMR (*Automatic Meter Reading*), as presented in [10], system with such remote reading for electrical energy consumption. This system is equipped with certain characteristics of AMI (*Advanced Meter Infrastructure*), as presented in [11], as it allows two-way communication between measuring and remote equipment, remote configuration of measuring and communication devices, and finally power management for consumer in terms of on/off control using the switching devices inside the field devices. The basic structure of such AMR/AMI system is presented in Figure 2.

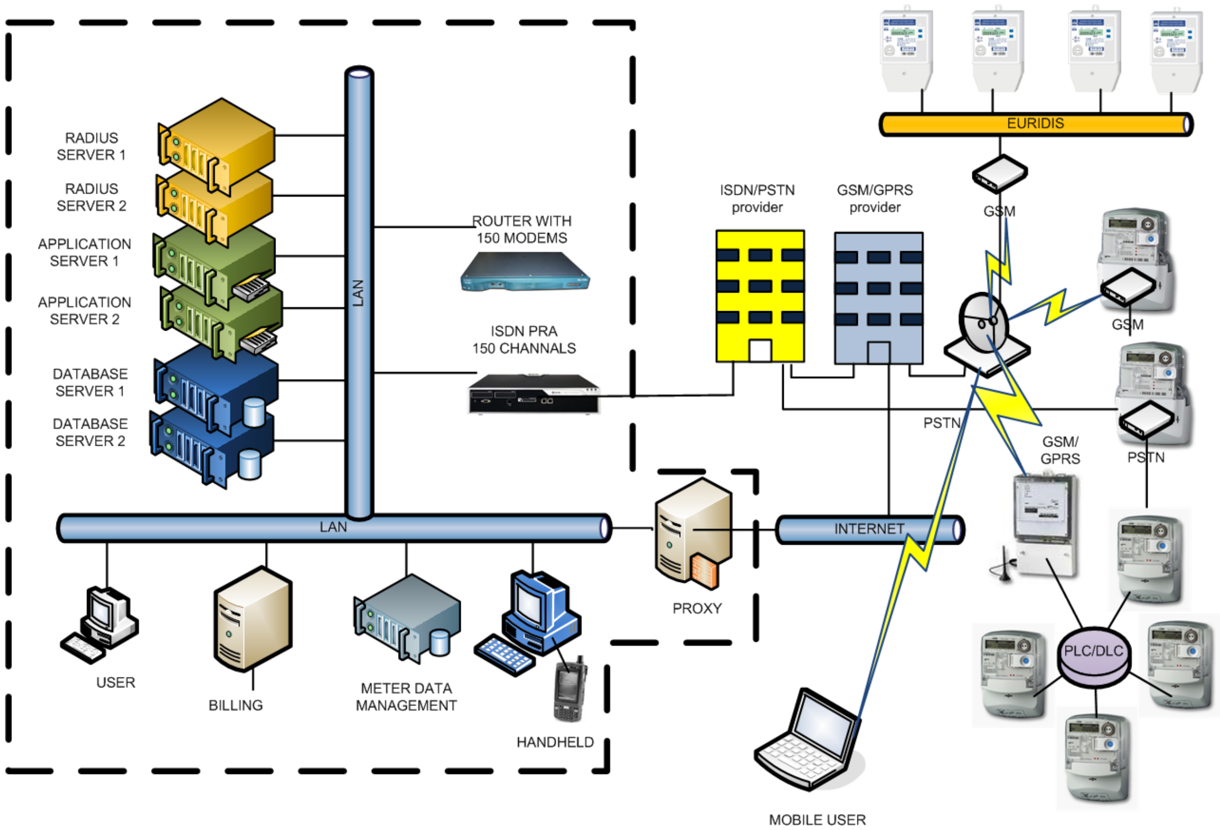

Figure 2. AMR/AMI system scheme

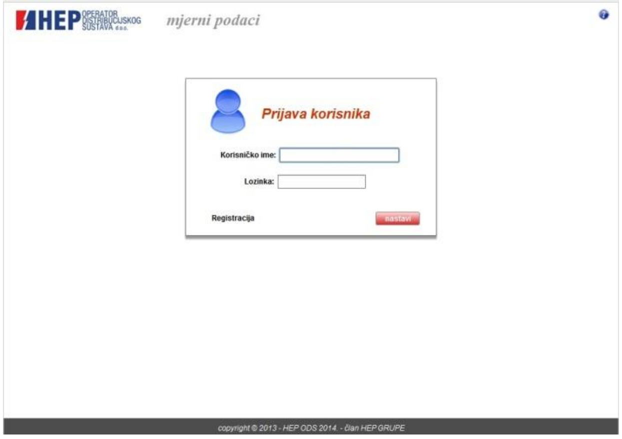

Figure 3. The consumer login interface for AMR/AMI monitor website

The website in Figure 3 is created for system consumers in order for them to be able to monitor their electrical energy consumption if they are equipped with one of the described measuring field devices and remote access. When consumer is logged in this website one can access and/or use 3 important measuring pieces of information in order to fully understand the way that he is supplied with electrical energy:

1. Three (3) months of historical measured data,
2. Download recorded data,
3. Use downloaded data for planning and energy management.

The monthly or semi-annual electricity consumption data is available for all other measuring field devices. All of these services are available with no charge to user. Random sample for history data website interface of active power is presented in Figure 4. The active power is presented as numerical values and graph, all in kW. The same website interface of reactive power is presented in Figure 5. The reactive power is presented as numerical values and graph, all in kVAr.

The sample of downloaded database for active power is presented in Figure 6. The database can be downloaded in CSV (comma separated value) file format. This kind of format is easily accessed through Microsoft Office Excel, Access, or any other standard database tool.

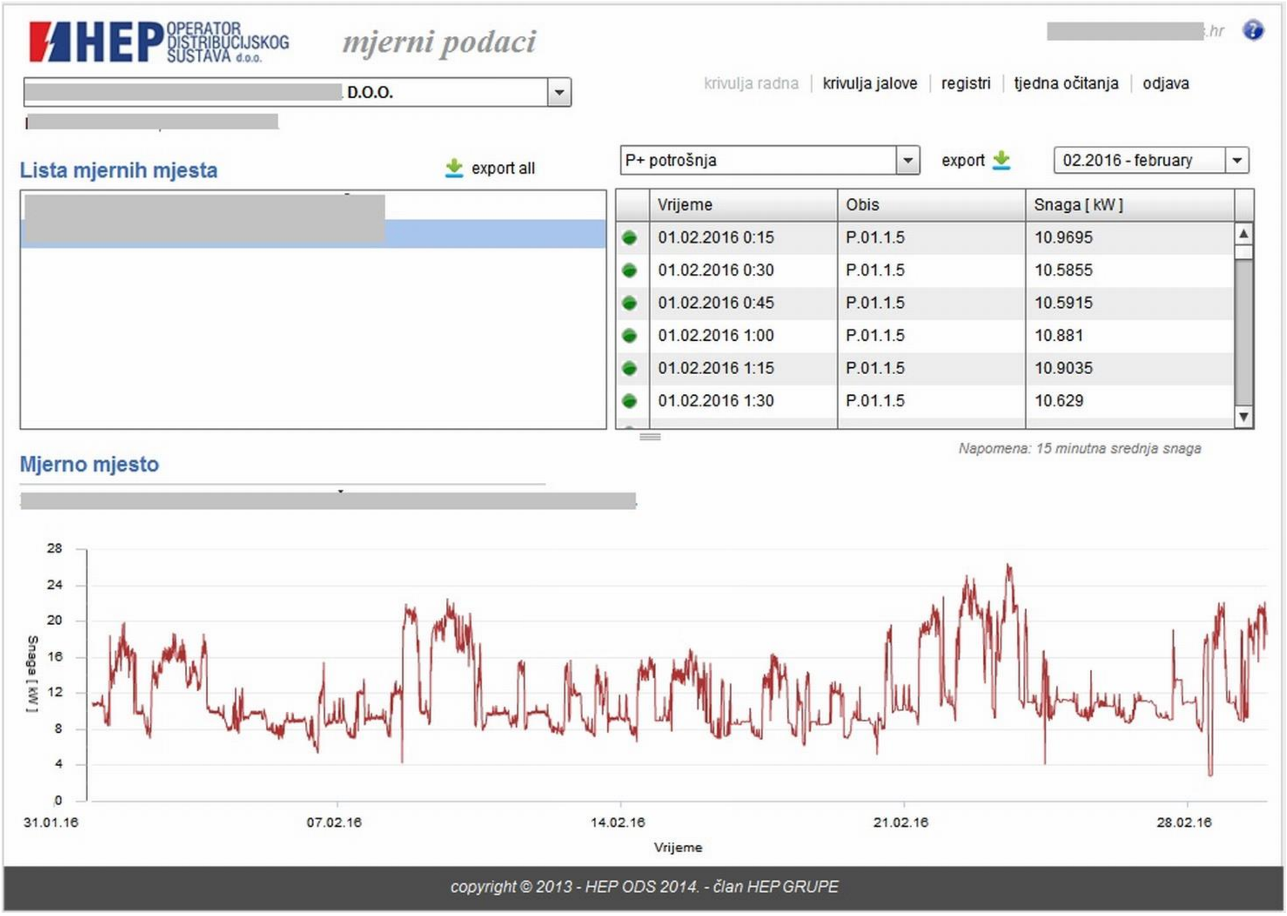

Figure 4. Website interface for history data of active power consumption, sample for random consumer

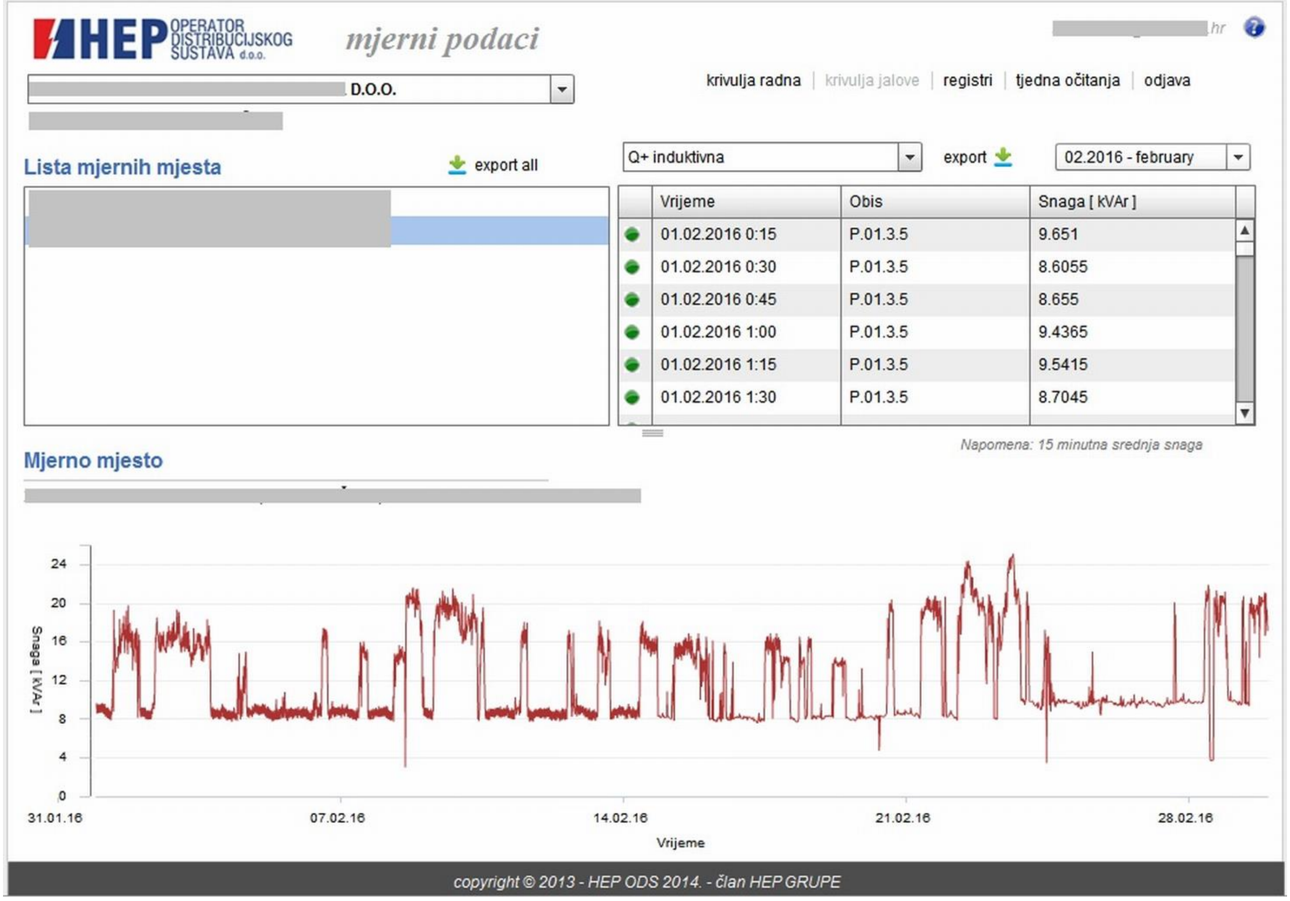

Figure 5. Website interface for history data of reactive power consumption, sample for random consumer

	A	B	C	D	E	F
1	OIB	Consumer	Meas. Point	Name	Address	Status
2	N/A	N/A	N/A	N/A	N/A	U
3	Meas. Point	Time	Meter	OBIS code	Power [kW]	Constant
4	N/A	1.2.2016 0:15	N/A	P.01.1.5	10,97	15
5	N/A	1.2.2016 0:30	N/A	P.01.1.5	10,586	15
6	N/A	1.2.2016 0:45	N/A	P.01.1.5	10,592	15
7	N/A	1.2.2016 1:00	N/A	P.01.1.5	10,881	15
8	N/A	1.2.2016 1:15	N/A	P.01.1.5	10,904	15
9	N/A	1.2.2016 1:30	N/A	P.01.1.5	10,629	15
10	N/A	1.2.2016 1:45	N/A	P.01.1.5	10,593	15
11	N/A	1.2.2016 2:00	N/A	P.01.1.5	10,86	15
12	N/A	1.2.2016 2:15	N/A	P.01.1.5	10,91	15

Figure 6. Example of downloaded/exported data

4. RESULTS AND ANALISYS

Measured data of electrical energy consumption is provided for random user in period from February 3 (Monday) until February 9 (Sunday) of 2014. Electrical power consumption measurement results for each day are presented in Figure 7. It can be seen that the user is intensively working every day in three shifts, except from Saturday 3rd shift until Monday 1st shift. Also, electrical power has partial oscillation while in full commission for all work shifts.

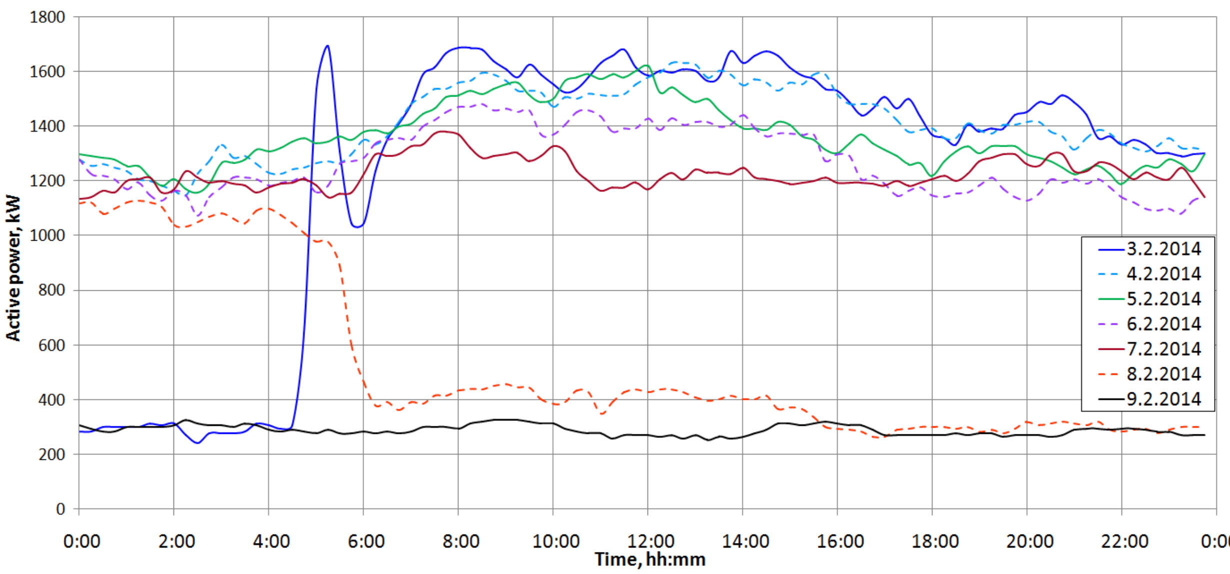

Figure 7. Electrical power consumption measurement results from February 3 until February 9 of 2014

From electrical power it is easy to calculate energy consumption by simple integration for each measured day. Electrical energy consumption of the user is presented in Figure 8.

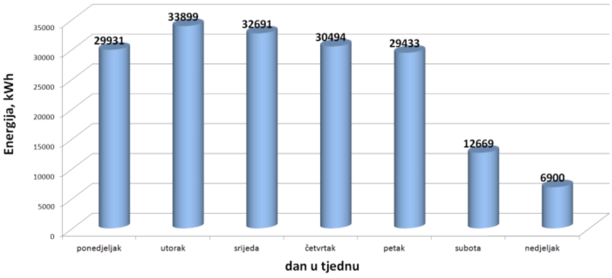

Figure 8. Electrical energy consumption from 03. February till 09. February of 2014

Standard analytic calculations can be applied to power and energy measured data of electrical energy consumption. The main results from available data are minimal, average and maximal power and energy values. These results are provided in Table 1.

Table 1. Consumer behavior analysis

	Minimum	Average	Maximum
P / kW	-	1048 kW	1692 kW
E / kWh	6900 kWh	25145 kWh	33899 kWh

Since power and energy are supposed to be self-sufficient, the analysis must be applied on daily basis. The results given in Table 2 are daily measured energy consumption cumulative. From these daily energies one can conduct a design of PV system.

Table 2. Consumer daily measured energy consumption cumulative

DATE	DAY	DAILY ENERGY kWh
3.2.2014	Monday	29931
4.2.2014	Tuesday	33899
5.2.2014	Wednesday	32691
6.2.2014	Thursday	30494
7.2.2014	Friday	29433
8.2.2014	Saturday	12669
9.2.2014	Sunday	6900

The PV system energy production shows average daily energy per kW of installed PV power for any month. The results are gained from on-line web tool PVGIS for Europe, available at [2]. For measured period (February) PV energy production is 2.23 kWh/kWpp. Therefore, the isolated PV system is derived from maximum necessary number of PV modules in Table 3. It is obvious that the maximum values in this measurement are gained in Tuesday. Therefore, the whole PV system is designed using the results in Tuesday, while some reserve is also applied. The reserve is supposed in order to cover any energy losses due to bad weather or any other reduce in energy production.

Table 3. Consumer daily measured PV power with number of modules

DATE	DAY	PV POWER kW	NR. OF MODULES pcs
3.2.2014	Monday	13421	53684
4.2.2014	Tuesday	15201	60804
5.2.2014	Wednesday	14659	58636
6.2.2014	Thursday	13674	54696
7.2.2014	Friday	13198	52792
8.2.2014	Saturday	5681	22724
9.2.2014	Sunday	3094	12376

In this case study PV system must be composed of 61000 PV modules with peak power of 250 W. This will ensure 15250 kW in described PV system. The battery block must ensure at least 33899 kWh and 1692 kW continuously. Finally, the inverter block must ensure roughly 1700 kW continuously.

$$k_{AVG} = \frac{P_{AVG}}{P_i} = \frac{1048}{15201} = 0.068943 \approx 6.9\% \quad (1)$$

$$k_{MAX} = \frac{P_{MAX}}{P_i} = \frac{1692}{15201} = 0.111308 \approx 11.1\% \quad (2)$$

In order to cover energy demand of consumer through PV plant it is necessary to invest in several times bigger installed power of PV modules and battery resources respectively to the average or maximum consumption, like gained in (1) and (2), and all because of daily electrical energy production characteristic for PV plant which is not related to daily electrical energy consumption characteristic for selected consumer.

5. CONCLUSION

In this paper the on-line webpage database is used to gain access to consumer behavior in order to improve design of PV plant in isolated operation. Measured data is also used for billing the electrical energy consumption to end user, and therefore is relevant for this case study. The results of PV plant resources are derived from maximum gained power of consumption, but also consumption behavior, which in this case has a great impact on PV plant design. The result is that PV plant is supposed to be almost 10 times bigger than maximum gained consumption power of installation, and almost 20 times bigger than average daily power consumption. Therefore, in this or similar cases it is necessary to ensure a high price of final product piece in order for PV plant energy production to be profitable.

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